Design of Engineering Curriculum Considering Sustainable Development Role

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Abstract- *Engineering education is a vital tool to be used for facing today's challenges and for building a better world without compromising the ability of future generation to met their own needs and hence the new engineers should be able to take the best technical solution for sustainable development of the world. A paradigm shift in engineering education becomes a necessity and accordingly, engineering education, must have an integrated approach to knowledge, attitudes, skills and values in teaching, incorporate disciplines of the social sciences and humanities and promote multidisciplinary teamwork. Universities need to review many aspects in engineering education such as; the curriculum, content of courses, teaching strategies and learning techniques, evaluation and assessment techniques, and quality control system. Engineering education must covers the current global issues such as global warming, material sustainability, natural resources, waste disposable, alternate energy resources, economical and social problems and other aspects which have a significant impact on Environment and sustainable development. This paper focuses on the design Engineering curriculum considering the role of sustainable development. The design was based on outcome based education and the sustainable development aspects were included in the objectives and outcomes of a specific engineering program. The percentage of the contribution of courses in a curriculum addressing sustainable developments was estimated using simple statistic.*

Index Term – *Engineering curriculum design, sustainable development, program outcomes, course outcomes*

INTRODUCTION

The main challenge of engineering education in sustainable development is how to help students gain contextualized knowledge and competencies which are connected with relevant cultural and collaborative environment instead of merely learning generalized knowledge and fixed skills [1,2]. In traditional engineering education, the program structures and curricula are means, not end and is process based education and hence it becomes difficult to measure the three dimensions of sustainability; environmental, economic and social. Awareness of Engineering Education for Sustainable development (EESD) is growing in many universities worldwide that wish to provide engineers with the skill in sustainability that industry requires and needs to remain globally competitive should not remain complacent[2].

In engineering education, learning outcomes are defined in the form of competencies. Some of these outcomes must satisfy sustainable development as per Barcelona declaration for EESD (2004)[3]. Definitions of what a student must know, understand and what actions he or she must be able to implement at the completion of a learning process are set. Sustainability can only be served by an open education, where students also have a crucial say in defining parameters of education mentioned above, on the basis that they are interested and competent in their own education and training. Hence, the lecturer-student-stakeholders cooperation and interaction is the major key in developing the new engineering education system. The following aspects of the educational process must be reviewed:

- Curriculum.
- The content of courses.
- Teaching strategies in the classroom.
- Teaching and learning techniques.
- Research methodology.
- Evaluation and assessment techniques.
- The participation of external bodies in developing and evaluating the curriculum.

- Quality control systems.

This paper focuses on the design Engineering curriculum considering the role of sustainable development. The design was based on outcome based education and the sustainable development aspects were included in the objectives and outcomes of a specific engineering program. The percentage of the contribution of courses in a curriculum addressing sustainable developments was estimated using simple statistic.

Design of Engineering Curriculum

Engineering education is now embracing an Outcome Based Education (OBE) approach. The approach now becomes important for an engineering degree to obtain accreditation from any Engineering Accreditation Council (EAC in Europe or ABEAT in USA) [4]:

At University o Nizwa, different disciplines of Engineering program are developed to prepare students to work for the benefit of humankind in a global context by solving engineering problems; applying fundamental principles using modern tools; functioning as team members and leading when appropriate [5]. It is very essential to include the elements of sustainable development in the objectives of any engineering program. Hence at UON, three major **objectives** were set for the engineering & Architecture College as follows:

a) To prepare graduates with sufficient knowledge in different fields of engineering together with appropriate skills and attitude to work in the industry.

b) To produce graduates who are creative and innovative, as well as, sensitive and responsible towards the society, cultures and environment

c) To produce graduates who are capable to work in advanced sustainable design and development at national and international level.

The first objective focuses on basic knowledge and fundamental engineering concepts and the 2nd objective covers the elements of sustainability while the third objective focuses on the sustainable design in global context.

The program outcomes defined by ABEAT and/or EUR-ACE were integrated with the requirement for sustainable development set by as Barcelona declaration for EESD (2004) (presented in the appendix) in order to re-engineer the engineers to face the new challenges in global context. Hence, at UON, upon graduating from any of the engineering program, the students are able to (program outcomes):

1. apply knowledge of mathematics and engineering sciences (K)
2. design and conduct experiment (S)
3. analyze and interpret data (K)
4. design a system, component or process to meet a requirement (K)
5. **apply the principles of sustainable design and development** (K,SD)
6. function effectively as an individual in a multidisciplinary group (A)
7. demonstrate the characteristics of a leader or a manager (A)
8. identify, formulate and provide creative/innovative/effective solution to the problem (S)
9. **describe of professional and ethical responsibility** (K,SD)
10. communicate effectively with engineers, other professionals and community at large (A)
11. **describe the impact of engineering solutions on the economy, society, culture and environment** (K,SD)
12. recognize the need for and able to engage in lifelong learning (A)
13. discuss the relevant contemporary issues (K)

14. use the skills, techniques and modern engineering tools for engineering practice (S)
15. **solve problems in advanced sustainable design and development.** (K,SD)

The above outcomes covers the Knowledge (K), Skill (S), Attitude (A) and aspect of Sustainable developments (SD) as indicated between brackets in each outcome. The outcomes in bold letters cover different aspects of sustainable development in engineering education (outcomes nos. 5,9,11 and 15). The program outcomes or student attributes are developed through a comprehensive curriculum design and application of appropriate teaching methodologies and strategies. Once the program objectives and program outcomes are finalized, faculty members would then developed the courses contents with related course outcomes [6]. The course outcomes are formulated for each course to address part or all of the stated program outcomes.
Figure 1 illustrates an example of course outcomes matrix for a specific course in the program. The correlation between each course outcomes (CO) and degree program outcomes (PO) was established for all the courses in the curriculum. These outcomes will be assessed according to a pre specified performance indicators as shown in Fig. 1. The matrices were built up using "0" and "1" concept. The value "1" will be assigned when a course specific outcome is addressing the program outcome; otherwise "0" value will be assigned. These matrices will provide a clear picture on the relevancy between the set of course outcomes and program outcomes suggested for specific program. The experts in each program are responsible building up these matrices using "0" and "1" concept as indicated earlier. The total summation of each column in each matrix represent the total number of times that a specified PO is addressed by the outcomes of the course as shown in Fig. 1.

These cumulative results of individual course shall be transferred to another matrix which correlate these cumulative results of all courses in the program with the program outcomes matrix as shown in Fig. 2. This new matrix represents the contribution of each course in addressing the PO. The total summation of the weights in each column in this matrix represents estimation on the number of times a specific outcome is addressed by all courses in the program. These weights are then converted to percentages and are presented in graphical form. The chart in Fig. 2 shows the percentage of the contribution of courses in a curriculum addressing the program outcomes. Furthermore, the chart will provide insight on the importance (weight) of a given PO addressed by the curriculum.

Finally the estimation of the percentages of Knowledge, Skill, Attitude and Sustainable development (or any other speciality) in a specified curriculum are estimated by adding the total weights of relevant PO and can be presented in triangular form as shown in Fig. 2. Hence for this example, the curriculum addresses K by 68% in which the role of sustainable development is 25%.

CONCLUSION

The program outcomes required by different Engineering Accreditation Councils such as ABEAT and EUR-ACE are integrated with the requirement for sustainable development to define the engineering program outcomes. The curriculum is designed by identifying courses and courses outcomes required to fulfill the program outcomes. Matrices correlating CO to PO are established and the results are transferred to cumulative courses outcomes-program outcomes matrix from which the percentage of the contribution of courses in a curriculum addressing sustainable developments was estimated using simple statistic.

REFERENCES

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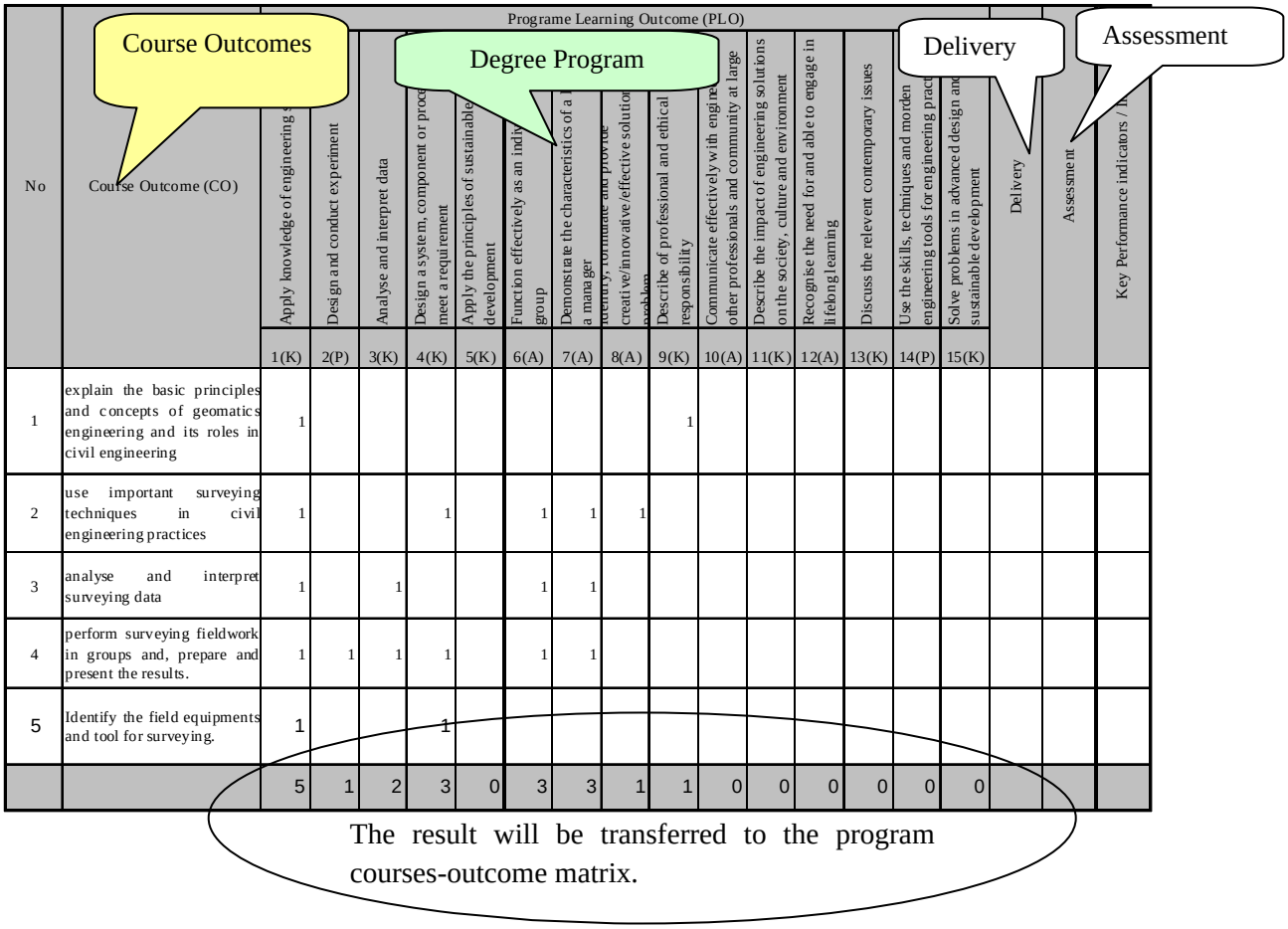

No	Course Outcome (CO)	Programe Learning Outcome (PLO)															Delivery	Assessment	Key Performance indicators / Ta
		Apply knowledge of engineering s	Design and conduct experiment	Analyse and interpret data	Design a system, component or proc meet a requirement	Apply the principles of sustainable development	Function effectively as an indiv group	Demonstrate the characteristics of a l a manager	Identify, formulate and provide creative/innovative/effective solution problem	Describe of professional and ethical responsibility	Communicate effectively with engine other professionals and community at large	Describe the impact of engineering solutions on the society, culture and environment	Recognise the need for and able to engage in lifelong learning	Discuss the relevent contemporary issues	Use the skills, techniques and morden engineering tools for engineering practi	Solve problems in advanced design and sustainable development			
		1(K)	2(P)	3(K)	4(K)	5(K)	6(A)	7(A)	8(A)	9(K)	10(A)	11(K)	12(A)	13(K)	14(P)	15(K)			
1	explain the basic principles and concepts of geomatics engineering and its roles in civil engineering	1								1									
2	use important surveying techniques in civil engineering practices	1			1		1	1	1										
3	analyse and interpret surveying data	1		1			1	1											
4	perform surveying fieldwork in groups and, prepare and present the results.	1	1	1	1		1	1											
5	Identify the field equipments and tool for surveying.	1			1														
		5	1	2	3	0	3	3	1	1	0	0	0	0	0	0			

FIGURE1 Course outcomes verses program outcomes

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
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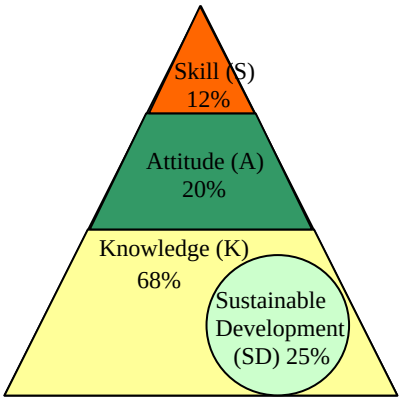
Program Outcomes

Courses in a curriculum

					Programme Outcomes (POs)														
					Apply knowledge of mathematics and engineering sciences	Design and conduct experiment	Analyze and interpret data	Design a system, component or process to meet the design requirement	Use principles of sustainable design and development	Ability to function effectively as a member of a team	Demonstrate leadership or managerial characteristics	Identify, formulate and provide creative/innovative/effective solution to the problem	Explain the professional and ethical responsibility	Communicate effectively with engineers, other professionals and community at large	Explain the impact of engineering solutions in societal, cultural, global and environmental context	Recognize the need for and are able to engage in lifelong learning	Discuss relevant contemporary issues related to engineering	Use necessary skills, techniques and modern engineering tools for engineering practice	Solve problems in advanced design and development
No.	**Sem**	**Course Code**	**Course Name**	**Credit**	**1(K)**	**2(P)**	**3(K)**	**4(K)**	**5(K)**	**6(A)**	**7(A)**	**8(K)**	**9(K)**	**10(A)**	**11(K)**	**12(A)**	**13(A)**	**14(P)**	**15(K)**
1		CIVL211	Engineering Mechanics	3(3+0)	6	0	0	0	0	1	1	1	0	0	0	0	0	0	0
2		CIVL212	Civil engineering Materials	3(2+1)	5	1	1	0	1	2	2	2	0	2	1	1	0	1	0
3		CIVL213	Fluid engineering Mechanics	3(2+1)	6	2	3	2	0	2	2	0	0	0	0	0	0	0	1
4		CIVL214	Geomatic Engineering	3(2+1)	5	1	2	3	0	3	3	1	1	0	0	0	0	0	0
5		ENGN 333	Industrial training	2(0+2)	1	0	0	1	1	2	2	1	1	3	1	1	1	2	1
6		CIVL215	Civil Engineering drawing	3(1+2)	6	0	0	4	2	2	1	1	0	0	0	0	0	1	1
7		CIVL221	Solid Mechanics	3(3+0)	4	0	2	1	0	1	1	1	0	0	1	0	0	1	0
8		CIVL321	Structural analysis-1	3(3+0)	5	3	6	5	0	1	1	0	0	0	0	0	0	1	0
9		CIVL322	Structural analysis-2	3(3+0)	4	0	3	0	0	1	1	3	0	0	0	0	0	3	1
10		CIVL323	Structural design-1	3(3+0)	5	0	4	4	3	1	1	4	1	0	1	1	0	4	1
11		CIVL421	Structural Design-2	3(3+0)	4	0	3	4	2	1	1	4	0	0	1	0	0	4	2
12		CIVL331	Engineering geology	3(2+1)	3	2	2	0	0	2	1	0	0	0	1	1	1	0	0
13		CIVL332	Soil Mechanics-1	3(2+1)	5	3	4	1	0	1	1	1	0	0	0	1	1	0	0
14		CIVL431	Soil Mechanics-2	3(3+0)	6	1	1	2	3	1	1	4	0	0	1	0	1	1	0
15		CIVL432	Foundation engineering	3(3+0)	5	1	4	3	3	1	1	5	0	1	0	1	0	4	0
16		CIVL241	Environmental engineering	3(3+0)	6	0	4	1	5	1	1	4	1	1	5	4	1	1	0
17		CIVL341	Hydrology	3(3+0)	5	0	4	3	0	0	0	0	0	0	0	0	0	0	0
18		CIVL342	Hydraulics	3(3+0)	6	1	3	1	1	0	0	5	0	0	1	1	0	1	0
19		CIVL441	Water and wastewater engineering	3(2+1)	6	3	5	4	3	2	2	1	0	0	1	2	2	1	0
20		CIVL351	Traffic Engineering	3(3+0)	4	1	3	1	4	0	0	4	1	0	4	0	0	2	0
21		CIVL451	Highway Engineering-1	3(2+1)	4	1	3	2	4	1	1	2	0	1	4	0	0	2	0
22		CIVL452	Highway engineering-2	3(3+0)	4	0	2	2	2	0	0	2	0	0	4	1	0	2	1
23		CIVL461	Project management	3(3+0)	4	0	2	3	2	1	1	3	4	3	3	0	1	4	0
24		CIVL462	Construction Methods and	3(3+0)	5	0	5	4	3	0	0	3	1	2	5	0	0	5	0
25		CIVL471	Design Project	3(1+2)	2	0	2	2	3	5	5	3	4	5	4	4	1	5	2
26		CIVL472	Final Year project-1	2(0+2)	3	2	2	2	2	3	2	2	0	1	1	3	1	4	3
27		CIVL 473	Final Year project-2	4(0+4)	3	2	2	2	2	3	2	2	0	1	1	3	1	4	3
28		CIVL521	Elective-1	3(3+0)	5	1	5	3	0	2	2	5	0	1	1	1	1	5	3
29		CIVL522	Elective-2	3(3+0)	6	0	5	5	4	2	2	6	1	0	2	2	1	6	5
30		CIVL523	Elective-3	3(3+0)	5	0	5	5	4	2	2	5	0	2	4	1	1	5	2
30		CIVL524	Elective-4	3(3+0)	4	0	3	2	1	0	0	2	0	0	1	1	2	2	2
31		CIVL531	Elective-5	3(3+0)	3	0	3	3	1	1	1	1	0	1	1	1	1	3	3
			TOTAL	122	**145**	**25**	**93**	**75**	**56**	**45**	**41**	**78**	**15**	**24**	**49**	**30**	**17**	**74**	**31**
			Percentage(%)		**18.17**	**3.13**	**11.65**	**9.40**	**7.02**	**5.64**	**5.14**	**9.77**	**1.88**	**3.01**	**6.14**	**3.76**	**2.13**	**9.27**	**3.88**

These results are presented in graphical form. Chart shows the percentage of the contribution of courses in a curriculum addressing the program outcomes



Summary of KSA in the curriculum of the program

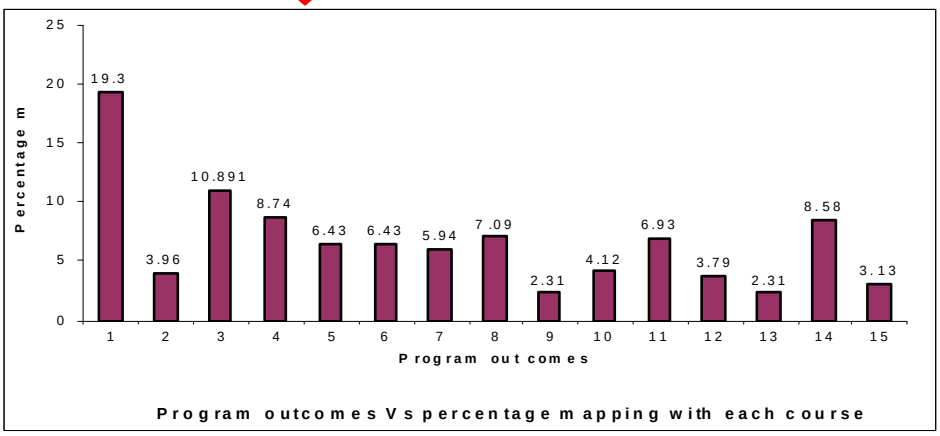


FIGURE 2 Courses-Po matrix and Analysis for KSA

Appendix

The Barcelona Declaration

Today's engineer must be able to:

- Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts.
- Understand the contribution of their work in different cultural, social and political contexts and take those differences into account.
- Work in multidisciplinary teams, in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management.
- Apply a holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts.
- Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more sustainable development.
- Apply professional knowledge according to deontological principles and universal values and ethics.
- Listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures.

Engineering education, with the support of the university community as well as the wider engineering and science community, must:

- Have an integrated approach to knowledge, attitudes, skills and values in teaching.
- Incorporate disciplines of the social sciences and humanities.
- Promote multidisciplinary teamwork.
- Stimulate creativity and critical thinking.
- Foster reflection and self-learning.
- Strengthen systemic thinking and a holistic approach.
- Train people who are motivated to participate and who are able to take responsible decisions.
- Raise awareness for the challenges posed by globalisation.